(NASA-CR-161121) TRANSISTOR STEP STRESS TESTING PROGRAM FOR JANTX2N4856 Final Report (DCA Reliability Lab., Sunnyvale, Calif.) 36 p HC A03/MF A01 CSCI 09A

N79-18200

G3/33 Unclas 14155

TRANSISTOR

STEP STRESS TESTING PROGRAM

MSFC/NASA CONTRACT NUMBER
NAS8-31944

FINAL REPORT
FOR
JANTX2N4856

JANUARY 1979

Prepared
For

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FOREWORD

This report is a summary of the work performed on NASA Contract NAS8-31944. The investigation was conducted for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama. The Contracting Officer's Technical Representative was Mr. F. Villella.

The short-term objective of this preliminary study of transistors, diodes, and FETS is to evaluate the reliability of these discrete devices, from different manufacturers, when subjected to power and temperature step stress tests.

The long-term objective is to gain more knowledge of accelerated stress testing for use in future testing of discrete devices, as well as to determine which type of stress should be applied to a particular device or design.

This report is divided as follows: description of tests, figures, tables, and appendix.

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1.0 INTRODUCTION

DCA Reliability Laboratory, under Contract NAS8-31944 for NASA/Marshall Space Flight Center, has compiled data for the purpose of evaluating the effect of power/temperature step stress when applied to a variety of semiconductor devices. This report covers the field effect transistor JANTX2N4856 manufactured by Texas Instruments and Teledyne.

A total of 48 samples from each manufacturer was submitted to the process outlined in Table 1. In addition, two control units were maintained for verification of the electrical parametric testing.

2.0 TEST REQUIREMENTS

2.1 Electrical

All test samples were subjected to the electrical tests outlined in Table 2 after completing the prior power/temperature step stress point. These tests were performed using the Fairchild Model 600 high-speed computer-controlled tester. Additional bench testing was also required on the devices.

2.2 Stress Circuit

The test circuit in Figure 1 was used to power all of the test devices during the power/temperature stress conditions. The V_{DS} was varied to obtain maximum rated power (MRP) on at least one of the

devices. All the remaining devices were subjected to no less than 90% of MPR. See Figure 1 for load resistance values and voltages.

2.3 Group I - Power Stress

Thirty-two units, 16 from each manufacturer, were submitted to the power stress process. The transistors were stressed in 500-hour steps at 50, 100, 125, 150 and 175 percent of MRP for a total of 2500 hours or until 50% or more of the devices failed.[1]* Electrical measurements were performed on all specified electrical parameters after each power step. See Table 1. (*See **Notes** at end of text.)

2.4 Group II - Temperature Stress 1

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress I Process. Group II was subjected to 1600 hours of stress at MRP in increments of 160 hours. The temperature was increased in steps of 25°C, commencing at 75°C and terminating at 300°C or until 50% or more of the devices failed.[1] Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

2.5 Group III - Temperature Stress II

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress II Process. Group III was subjected to 112 hours of stress at MRP in increments of 16 hours. The temperature was

increased in steps of 25°C, commencing at 150°C and terminating at 300°C or until 50% or more of the devices failed.[1] Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

3.0 DISCUSSION OF TEST RESULTS

3.1 Group I - Power Stress

3.1.1 **Texas Instruments.** The T.I. sample lot completed the entire 2500-hour Group I testing with three catastrophic failures. The first failure occurred 50 hours into the 50% MRP. Serial Number 1183 failed the maximum $I_{D(OFF)}$ limit. The next failure occurred 500 hours into the 125% MRP step. Serial Number 1181 failed the maximum $I_{D(OFF)}$ limit. The last failure occurred 150 hours into the 150% MRP step. Serial Number 1184 failed the maximum $I_{D(OFF)}$ limit. Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{D(OFF)}$ changed 13.06 nA from an initial mean of 13.13 nA to a final mean of 71.23 pA.

2) The mean value for $r_{ds(ON)}$ changed .50 Ω from an initial mean of 18.64 Ω to a final mean of 18.14 Ω. The control units for this sample lot remained constant throughout the entire Group I testing.

3.1.2 **Teledyne.** The Teledyne sample lot completed the entire 2500-hour Group I testing with one catastrophic failure. The failure occurred 25 hours into the 125% MRP step. Serial Num-

ber 9171 failed the maximum $I_{D(OFF)}$ limit. Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{D(OFF)}$ changed 295.1 pA from an initial mean of 205.0 pA to a final mean of 500.1 pA.

2) The mean value for $r_{ds(ON)}$ changed .11 Ω from an initial mean of 20.16Ωto a final mean of 20.05Ω. The control units for this sample lot remained constant throughout the entire Group I testing.

3.1.3 **Statistical Summary - Group I.** Table 4 outlines the results of Group I - power stress process for all of the specified electrical parameters and all measurement points for both Texas Instruments and Teledyne.

3.2 Group II - Temperature Stress I

3.2.1 **Texas Instruments.** The T.I. Sample lot completed the entire 1600-hour Group II testing with 16 catastrophic failures. The first failure occurred 160 hours into the 75°C-temperature step. Serial Number 1186 failed the maximum $I_{D(OFF)}$ limit. The next failures occurred 160 hours into the 125°C-temperature step. Serial Numbers 1188 and 1191 failed the maximum $I_{D(OFF)}$ limit. The next failure occurred 160 hours into the 225°C-temperature step. Serial Number 1199 failed the maximum $I_{D(OFF)}$ limit. The next three failures occurred 160 hours into the 275°C-temperature step. Serial Number 1190 failed the maximum $I_{D(OFF)}$ limit. Serial Numbers 1194 and 1200 failed

the maximum $r_{ds(ON)}$ limit. The last nine failures occurred 160 hours into the 300°C-temperature step. Serial Numbers 1192 and 1195 failed the maximum $r_{ds(ON)}$ limit. Serial Numbers 1185, 1187, 1189, 1193, 1196, 1197, and 1198 failed the maximum limits for both $I_{D(OFF)}$ and $r_{ds(ON)}$. Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{D(OFF)}$ changed 8.20 mA from an initial mean of 9.938 pA to a final mean of 8.20 mA.

2) The mean value for $r_{ds(ON)}$ changed 423.41Ω from an initial mean of 19.99Ω to a final mean of 443.4Ω. The control units for this sample lot remained constant throughout the entire Group II testing.

3.2.2 Teledyne. The Teledyne sample lot completed the entire 1600-hour Group II testing with 14 catastrophic failures. The first failure occurred 160 hours into the 75°C-temperature step. Serial Number 9178 failed the maximum $I_{D(OFF)}$ limit. The next four failures occurred 160 hours into the 275°C-temperature step. Serial Numbers 9186 and 9188 failed the maximum $I_{D(OFF)}$ limit. Serial Number 9187 failed the maximum $r_{ds(ON)}$ limit. Serial Number 9181 failed the maximum limits for both $I_{D(OFF)}$ and $r_{ds(ON)}$. The last nine failures occurred 160 hours into the 300°C-temperature step. Serial Numbers 9175, 9177, 9179, 9184, 9189, and 9190 failed the maximum $I_{D(OFF)}$ limit. Serial Number 9176 failed the maximum $r_{ds(ON)}$ limit. Serial Numbers 9180 and 9185 failed the maximum limits for both $I_{D(OFF)}$ and $r_{ds(ON)}$. Typical

characteristics of this sample lot's performance were:

1) The mean value for $I_{D(OFF)}$ changed 2.35 mA from an initial mean of 34.31 pA to a final mean of 2.35 mA.

2) The mean value for $r_{ds(ON)}$ changed 14.48Ω from an initial mean of 22.90Ω to a final mean of 37.38Ω. The control units for this sample lot remained constant throughout the entire Group II testing.

3.2.3 Statistical Summary - Group II. Table 5 outlines the results of Group II - Temperature Stress I testing for all of the specified electrical parameters and all of the measurement points pertaining to both Texas Instruments and Teledyne.

3.3 Group III - Temperature Stress II

3.3.1 Texas Instruments. The T.I. sample lot completed the entire 112-hour Group III testing with five catastrophic failures. The first failure occurred 16 hours into the 150°C-temperature step. Serial Number 1207 failed the maximum $I_{D(OFF)}$ limit. The next failure occurred 16 hours into the 175°C-temperature step. Serial Number 1216 failed the maximum $I_{D(OFF)}$ limit. The next two failures occurred 16 hours into the 275°C-temperature step. Serial Numbers 1209 and 1213 failed the maximum $I_{D(OFF)}$ limit. The last failure occurred 16 hours into the 300°C-temperature step. Serial Number 1203 failed the maximum $I_{D(OFF)}$ limit. In

addition to the catastrophic failures, Serial Number 1208 was removed from the sample lot as a MIL-S-19500 $I_{D(OFF)}$ limit failure. Typical characteristics of this sample lot's performance were:

1) The mean value for $I_{D(OFF)}$ changed 8.46 nA from an initial mean of 10.19 pA to a final mean of 8.47 nA.

2) The mean value for $r_{ds(ON)}$ changed 1.67Ω from an initial mean of 20.25Ω to a final mean of 21.92Ω. The control units for this sample lot remained constant throughout the entire Group III testing.

3.3.2 **Teledyne**. The Teledyne sample lot completed the entire 112-hour Group III testing with three catastrophic failures. The first failure occurred 16 hours into the 150°C-temperature step. Serial Number 9192 failed the maximum $I_{D(OFF)}$ limit. The next failure occurred 16 hours into the 200°C-temperature step. Serial Number 9155 failed the maximum $I_{D(OFF)}$ limit. The last failure occurred 16 hours into the 275°C-temperature step. Serial Number 9195 failed the maximum $r_{ds(ON)}$ limit. Typical characteristics of the sample lot's performance were:

1) The mean value for $I_{D(OFF)}$ changed 132.07 pA from an initial mean of 12.13 pA to a final mean of 144.2 pA.

2) The mean value for $r_{ds(ON)}$ changed 1.41Ω from an initial mean of 22.72Ω to a final mean of 24.13Ω. The control units for this sample lot remained constant throughout the entire Group III testing.

3.3.3 Statistical Summary - Group III. Table 6 outlines the results for Group III - Temperature Stress II testing for each of the specified electrical parameters and all measurement points for both Texas Instruments and Teledyne.

4.0 FINAL DATA SUMMARY

Table 7 statistically summarizes the change in the mean value from the zero-hour data to the final data. The graphs of Figures 2 and 4 plot the cumulative percent failures versus the temperature stress level for Group II - Temperature Stress I, and Group III - Temperature Stress II. The graphs of Figures 3 and 5 plot the time step for Group II (160 hours) and Group III (16 hours) versus the temperatures T_1 and T_2 calculated from Figures 2 and 4. Tables 8 and 9 summarize the failures encountered for all three stress groups. The failures are separated into two categories: catastrophic failures in Table 8 and parametric failures in Table 9. The data from Table 8 was used as a source for the graphs in Figures 2 and 4. Figures 2 and 4 were used as a source for the graphs in Figures 3 & 5 respectively. Junction temperature is plotted on an inverse hyperbolic scale.

5.0 CONCLUSIONS

The Group II and III stress testing proved to be the most detrimental of the three groups for both manufacturers. Because of the similar failure mode

observed in both groups, failure analysis was performed on samples from the Group II testing only. Failure analysis points out that the majority of the devices exhibit, in various degrees, the effects of surface charges and metal migration. The worst case was Texas Instruments' sample Number 1185 where the aluminum actually melted. This resulted in shorting the source and drain junctions. Note that aluminum-silicon eutectic melts at approximately 577°C, which indicates the extreme junction temperature reached by these samples.

A plot showing cumulative failure distribution for Groups II and III was drawn for the Texas Instruments and Teledyne sample lots (Figures 2 and 3, and 4 and 5 respectively). Figures 2 and 3 display the data for the Texas Instruments lot used to calculate an activation energy of .98eV. Figures 4 and 5 display the data for the Teledyne lot used to calculate an activation energy of .83eV.

A broken circle around a marked point, on the graph, indicates a freak failure not calculated as part of the regression line. A solid circle around a marked point indicates an isolated main failure point. The regression line was calculated using the least squares method.

In Figures 2 and 4, the Group II failure points at 475° were not calculated into the regression lines because of a change in the failure mechanism.

The activation energy was calculated from the formula:

$$E = \left[\ell n \left(\frac{t_1}{t_2} \right) \right] \left[\frac{8.63 \times 10^{-5} \text{ eV/}^{\circ}\text{K}}{\left(\frac{1}{T_1 + 273} \right) - \left(\frac{1}{T_2 + 273} \right)} \right] \text{eV}$$

Where: t_1 = step of Group II - Temp Stress I = 160 hrs.

t_2 = step of Group III - Temp Stress II = 16 hrs.

T_1 = temperature in $^{\circ}$C of 16% failure for Group II.

T_2 = temperature in $^{\circ}$C of 16% failure for Group III.

NOTES

[1] Conditions for failure:

A) Open or short

B) Leakage exceeds MIL limit by 100 times

C) Other parameters exceed MIL limits by 50% or greater.

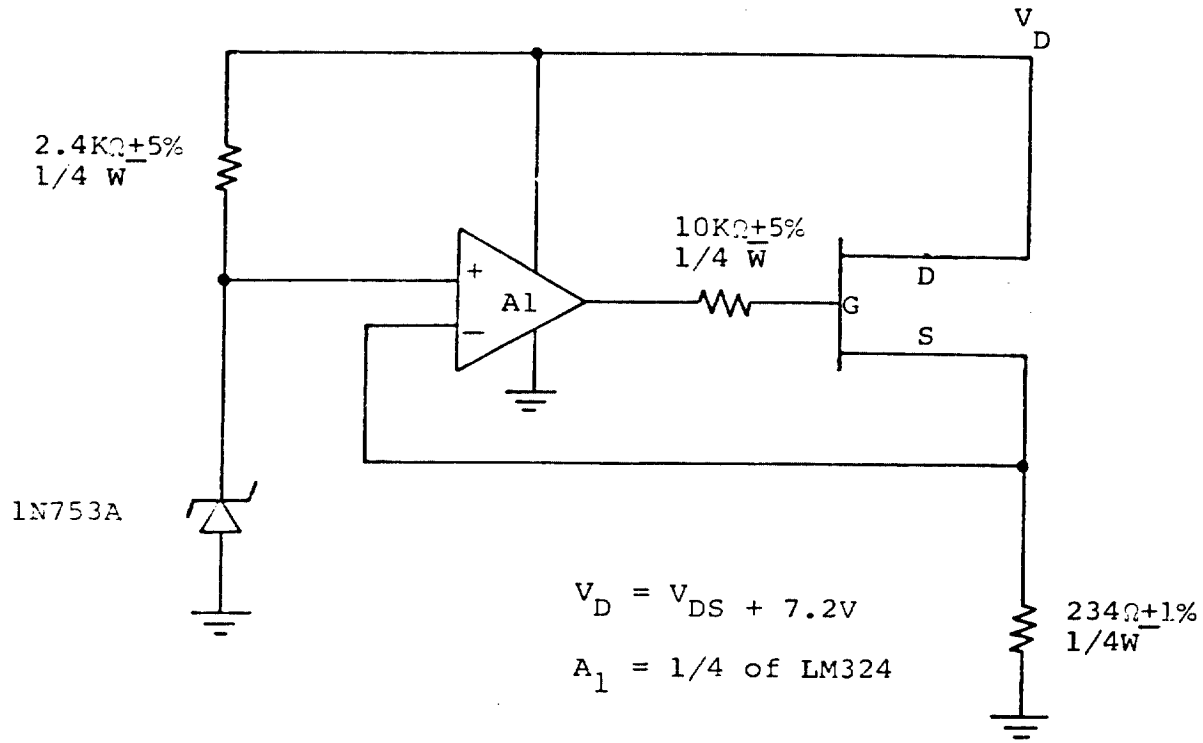
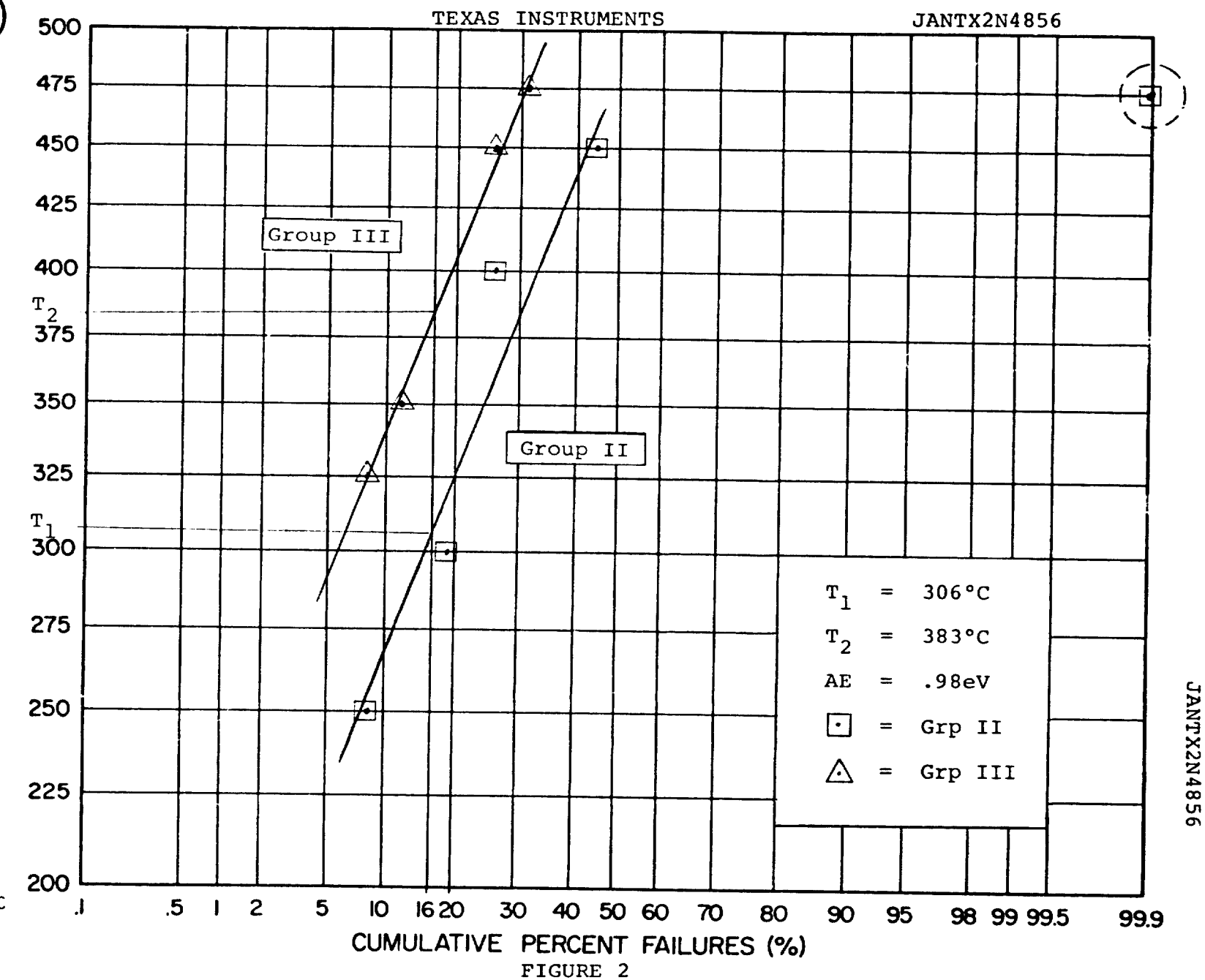


FIGURE 1
Power/Temperature Stress Circuit

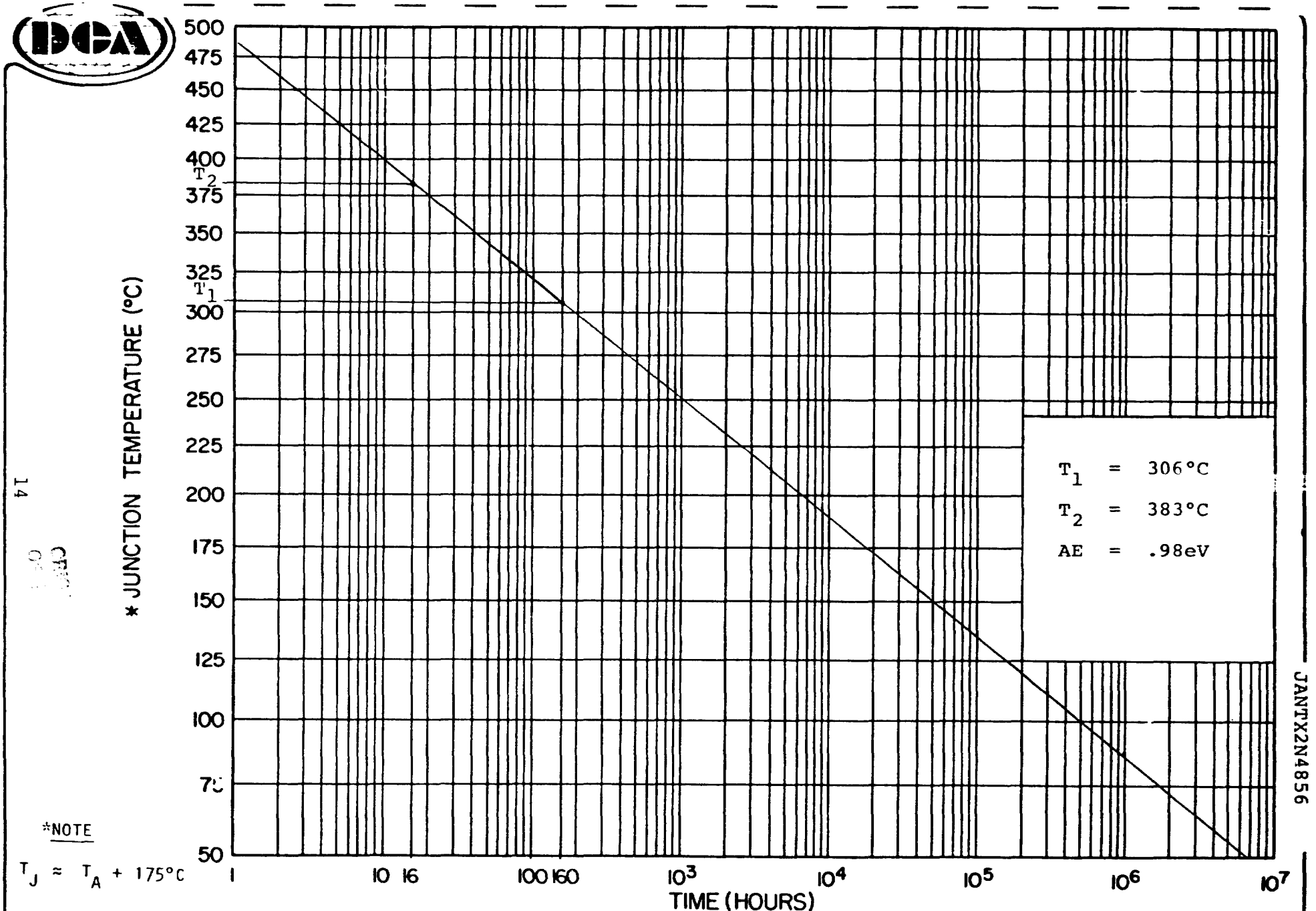


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 2

Cumulative Percent Failures Versus Junction Temperature, Texas Instruments

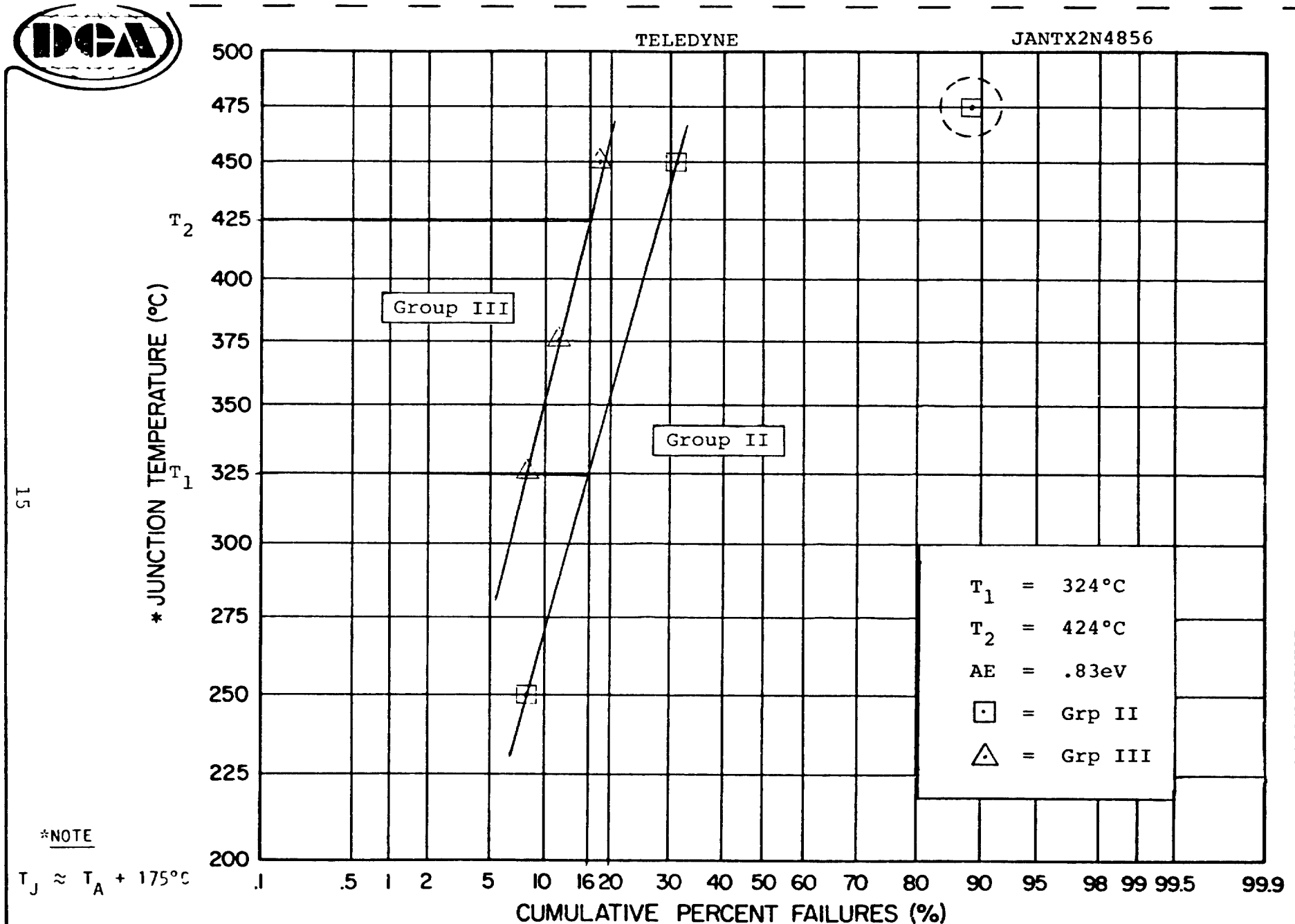


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 3

Time Steps Versus Junction Temperature, Texas Instruments

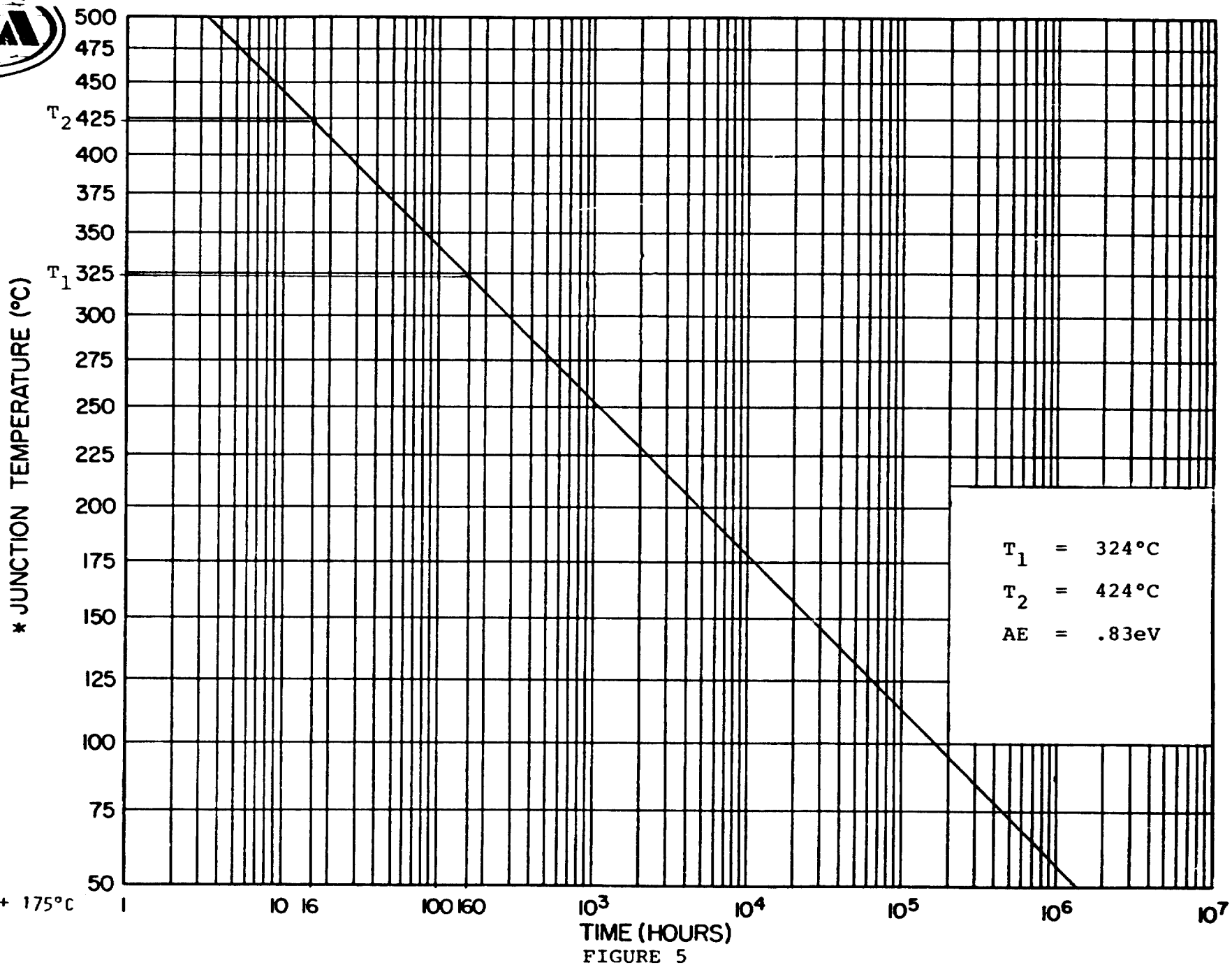


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 4

Cumulative Percent Failures Versus Junction Temperature, Teledyne

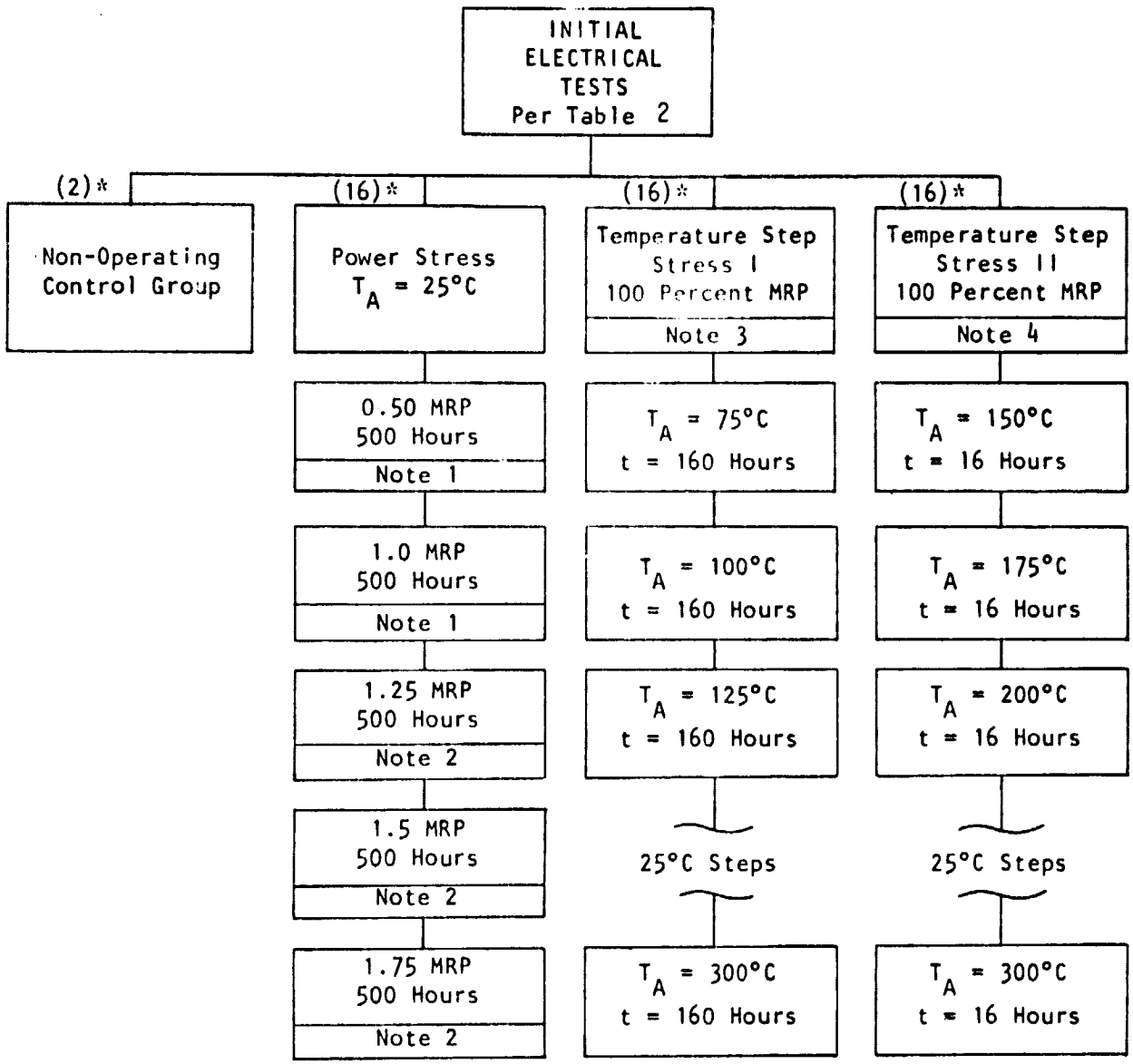


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 5
Time Steps Versus Junction Temperature, Teledyne

TABLE 1
TEST FLOW DIAGRAM



*Quantity per manufacturer (Texas Instruments & Teledyne)

NOTES:

1) Electrical measurements per Table 2 were made at 50, 150, 250 and 500 hours.
2) Electrical measurements per Table 2 were made at 10, 25, 50, 150, 250 and 500 hours.
3) Electrical measurements per Table 2 were made at the end of each 160 hours.
4) Electrical measurements per Table 2 were made at the end of each 16 hours.

TABLE 2
PARAMETERS AND TEST CONDITIONS

PARAMETER	CONDITIONS	SPEC. LIMIT		CAT. LIMIT		UNITS
		MIN	MAX	MIN	MAX	
$I_{D(OFF)}$	@VDS = 15 V, VGS = -10V	--	.25	--	25	nA
r_{ds}	@VGS = 0, I_D = 0, f = 1KHz, I_d = 100 μA(AC)(RMS)	--	25	--	37.5	Ω

NOTES: [1] In addition, any open or short shall be considered catastrophic.

TABLE 3
POWER STRESS BURN-IN CONDITIONS

I_D = 26.5 mA	
VDS =	Percent P_D
6.8 V	50
13.6 V	100
17.0 V	125
20.4 V	150
23.8 V	175

NOTE
FOR TABLES
4 THROUGH 7

The minimum/maximum initial and final data generally have an absolute accuracy of ±1% of the reading and ± one digit except for readings greater than 9.99mA which have an absolute accuracy of ±2% of the reading and ± one digit. The data also have a resolution for four digits. The standard deviations, means, delta means, and average means are, therefore, valid indicators of trends over time and temperature, excepting the minor statistical computer error of supplying a constant number of significant digits.

DCA

TABLE 4
GROUP I – POWER STRESS DATA SUMMARY

PARAMETER	$I_{D(OFF)}$ = .25 nA(MAX)		r_{ds} = 25Ω (MAX)					
CONDITIONS AND LIMIT	@VDS=15 V, VGS= -10V		VGS = 0, I_D = 0 f=1KHz, I_d = 100μA(RWS)					
IDENTIFICATION	TEXAS INSTRUMENTS	TELEDYNE	TEXAS INSTRUMENTS	TELEDYNE				
INITIAL DATA								
MIN VALUE	3.00 pA	4.00 pA	16.10 Ω	15.80 Ω				
MAX VALUE	210.0 nA	2.86 nA	23.10 Ω	23.80 Ω				
MEAN	13.13 nA	205.0 pA	18.64 Ω	20.16 Ω				
STD DEV	50.83 nA	686.4 pA	1.718 Ω	2.559 Ω				
INTERIM DATA								
POWER 50 TO 125% Δ MEAN VALUE								
50% POWER								
50 HRS	*174.37 nA	40.1 pA	.62 Ω	1.10 Ω				
150 HRS	-13.13 nA	187.3 pA	-.57 Ω	1.00 Ω				
250 HRS	-13.12 nA	314.7 pA	.12 Ω	.15 Ω				
500 HRS	-13.12 nA	301.1 pA	.39 Ω	.51 Ω				
100% POWER								
550 HRS	-13.12 nA	293.3 pA	-.48 Ω	.07 Ω				
650 HRS	-13.13 nA	148.6 pA	.20 Ω	.25 Ω				
750 HRS	-13.12 nA	452.7 pA	.32 Ω	.59 Ω				
1000 HRS	-13.12 nA	1.153 nA	1.70 Ω	2.48 Ω				
125% POWER								
1010 HRS	-13.13 nA	325.4 pA	.47 Ω	.65 Ω				
1025 HRS	-13.12 nA	* 1.444 nA	-.17 Ω	.16 Ω				
1050 HRS	-13.12 nA	-46.3 pA	-.42 Ω	-.02 Ω				
1150 HRS	-13.11 nA	77.2 pA	-.25 Ω	.35 Ω				
1250 HRS	-13.11 nA	90.1 pA	-.49 Ω	.05 Ω				
1500 HRS	*-10.32 nA	91.9 pA	-.52 Ω	.07 Ω				

(continued on second sheet)

TABLE 4 (Cont'd)
GROUP I – POWER STRESS DATA SUMMARY

(continued from first sheet)

PARAMETER	$I_{D(OFF)}$= .25 nA(MAX)		r_{ds} = 25 Ω (MAX)					
CONDITIONS AND LIMITS	@VDS=15 V, VGS = -10 V		VGS = 0, I_D = 0 f=1KHz, I_d=100uA(RWS)					
IDENTIFICATION	TEXAS INSTRUMENTS	TELEDYNE	TEXAS INSTRUMENTS	TELEDYNE				
INITIAL DATA								
MIN VALUE	3.00 pA	4.00 pA	16.10 Ω	15.80 Ω				
MAX VALUE	210.0 nA	2.86 nA	23.10 Ω	23.80 Ω				
MEAN	13.13 nA	205.0 pA	18.64 Ω	20.16 Ω				
STD DEV	50.83 nA	686.4 pA	1.718 Ω	2.559 Ω				
INTERIM DATA								
POWER 150 TO 175% Δ MEAN VALUE								
150% POWER								
1510 HRS	-7.44 nA	174.7 pA	-.38 Ω	.09 Ω				
1525 HRS	-13.08 nA	498.1 pA	-.40 Ω	.11 Ω				
1550 HRS	-13.08 nA	538.9 pA	-.23 Ω	.25 Ω				
1650 HRS	*486.97 nA	508.7 pA	-.19 Ω	.27 Ω				
1750 HRS	-13.04 nA	180.9 pA	-.42 Ω	.17 Ω				
2000 HRS	-13.03 nA	182.8 pA	-.36 Ω	.19 Ω				
175% POWER								
2010 HRS	-12.76 nA	266.7 pA	-.65 Ω	-.11 Ω				
2025 HRS	-12.44 nA	266.7 pA	-.53 Ω	.04 Ω				
2050 HRS	-12.88 nA	271.5 pA	-.31 Ω	.21 Ω				
2150 HRS	-12.96 nA	278.5 pA	-.69 Ω	-.09 Ω				
2250 HRS	-13.04 nA	282.8 pA	-.77 Ω	-.06 Ω				
2500 HRS	-13.06 nA	295.1 pA	-.50 Ω	-.11 Ω				
FINAL DATA								
MIN VALUE	4.00 pA	5.00 pA	15.80 Ω	15.50 Ω				
MAX VALUE	770.0 pA	7.00 nA	21.30 Ω	23.40 Ω				
MEAN	71.23 pA	500.1 pA	18.14 Ω	20.05 Ω				
STD DEV	202.3 pA	1.738 nA	1.353 Ω	2.566 Ω				

*NOTE: Catastrophic Rejects removed from data after this point.

TABLE 5

GROUP II TEMP STRESS I DATA SUMMARY

PARAMETERS	$I_{D(OFF)}$=.25 nA(MAX)		r_{ds}=25Ω (MAX)					
CONDITIONS AND LIMITS	@ VDS=15 V, VGS= -10 V		VGS=0, I_D = 0 f=1KHz, I_d=100 μA(RMS)					
IDENTIFICATION	TEXAS INSTRUMENTS	TELEDYNE	TEXAS INSTRUMENTS	TELEDYNE				
INITIAL DATA								
MIN VALUE	2.00 pA	7.00 pA	17.10 Ω	19.10 Ω				
MAX VALUE	35.0 pA	87.00 pA	23.10 Ω	25.00 Ω				
MEAN	9.938 pA	34.31 pA	19.99 Ω	22.90 Ω				
STD DEV	9.270 pA	28.25 pA	1.627 Ω	1.715 Ω				
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS / TEMP(T_A)								
160 / 75°C	34.65 nA	19.99 nA	.09 Ω	-.84 Ω				
320 / 100°C	114.06 pA	-9.91 pA	-.25 Ω	-.45 Ω				
480 / 125°C	25.71 nA	-11.38 pA	-.84 Ω	-.69 Ω				
640 / 150°C	4.03 pA	-7.58 pA	-.89 Ω	-1.29 Ω				
800 / 175°C	74.14 pA	-7.98 pA	-.66 Ω	-1.41 Ω				
960 / 200°C	188.76 pA	-15.04 pA	-.19 Ω	-1.48 Ω				
1120 / 225°C	336.36 pA	-9.24 pA	1.30 Ω	-.01 Ω				
1280 / 250°C	663.56 pA	542.79 pA	5.01 Ω	1.51 Ω				
1440 / 275°C	*7.33 μA	*1.425 A	*67.95 Ω	8.61 Ω				
1600 / 300°C	*8.20 mA	*2.35 mA	*423.41 Ω	*14.48 Ω				
FINAL DATA								
FINAL TEMP (T_A)	300°C	300°C	300°C	300°C				
MIN VALUE	4.80 pA	5.00 pA	46.0 Ω	21.70 Ω				
MAX VALUE	29.00 mA	8.90 mA	738.0 Ω	82.00 Ω				
MEAN	8.20 mA	2.35 mA	443.4 Ω	37.38 Ω				
STD DEV	11.32 mA	3.405 mA	321.3 Ω	17.87 Ω				

*NOTE: CATASTROPHIC REJECTS REMOVED FROM DATA AFTER THIS POINT.

TABLE 6

GROUP III TEMP STRESS II DATA SUMMARY

PARAMETERS	$I_{D(OFF)}$=.25 nA(MAX)		r_{ds}=25.0 Ω(MAX)					
CONDITIONS AND LIMITS	@VDS=15 V, VGS = -10 V		VGS=0, I_D=0 f=1KHz, I_d = 100 μA(RMS)					
IDENTIFICATION	TEXAS INSTRUMENTS	TELEDYNE	TEXAS INSTRUMENTS	TELEDYNE				
INITIAL DATA								
MIN VALUE	2.00 pA	4.00 pA	17.40 Ω	18.70 Ω				
MAX VALUE	47.00 pA	47.00 pA	23.20 Ω	25.00 Ω				
MEAN	10.19 pA	12.13 pA	20.25 Ω	22.72 Ω				
STD DEV	12.70 pA	11.50 pA	1.361 Ω	2.094 Ω				
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS / TEMP (T_A)								
16 / 150°C	*81.50 nA	500.0 nA *	-1.02 Ω	-.56 Ω				
32 / 175°C	* 2.78 nA	1.66 nA	-1.26 Ω	-.01 Ω				
48 / 200°C	51.10 pA	*12.07 nA	-.41 Ω	-.47 Ω				
64 / 225°C	241.91 pA	-4.42 pA	-1.39 Ω	-1.06 Ω				
80 / 250°C	1.88 nA	-4.42 pA	-1.30 Ω	-.53 Ω				
96 / 275°C	*137.60 nA	1.23 pA	.02 Ω	* 1.60 Ω				
112 / 300°C	8.46 nA	132.07 pA	1.67 Ω	1.41 Ω				
FINAL DATA								
FINAL TEMP (T_A)	300°C	300°C	300°C	300°C				
MIN VALUE	6.00 pA	5.00 pA	19.20 Ω	19.10 Ω				
MAX VALUE	92.00 nA	720.0 pA	24.70 Ω	35.40 Ω				
MEAN	8.47 nA	144.2 pA	21.92 Ω	24.13 Ω				
STD DEV	26.42 nA	196.6 pA	1.613 Ω	4.509 Ω				

* NOTE: CATASTROPHIC REJECTS REMOVED FROM DATA AFTER THIS POINT.

TABLE 7
FINAL DATA SUMMARY

PARAMETER	SPECIFICATIONS LIMIT		UNITS	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
					POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
	MIN	MAX			TEXAS INSTRUMENTS	TELEDYNE	TEXAS INSTRUMENTS	TELEDYNE	TEXAS INSTRUMENTS	TELEDYNE
$I_{D(OFF)}$		-.25	nA		+13.722*	+.33148*	+820739.2*	+235144.6*	+33.216*	+73.408*
r_{ds}		-25.0	Ω		-.17346	+.32192	+49.493*	+1.8430*	-.52714*	+.05429*

*NOTE: CATASTROPHIC REJECTS REMOVED FROM DATA

TABLE 8 STEP STRESS CATASTROPHIC FAILURE SUMMARY

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	1	A	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	0	-	0	-
15 hr.	0	-	1	A
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	1	A	0	-
150% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	1	A	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
175% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	1	A	1	A
100° C	0	-	0	-
125°C	2	A	0	-
150°C	0	-	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	1	A	0	-
250°C	0	-	0	-
275°C	1 / 2	A / B	2 / 1 / 1	A / C / B
300°C	2 / 7	B / C	6 / 2 / 1	A / C / B

GROUP III 16 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	1	A	1	A
175°C	1	A	0	-
200°C	0	-	1	A
225°C	0	-	0	-
250°C	0	-	0	-
275°C	2	A	1	B
300°C	1	A	0	-

MFR "A" = TEXAS INSTRUMENTS

MFR "B" = TELEDYNE

NOTES: (A) $I_{D(OFF)} > 25$ nA

(B) $r_{ds(ON)} > 37.5\ \Omega$

(C) $I_{D(OFF)} > 25$ nA AND $r_{ds(ON)} > 37.5\ \Omega$

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TABLE 9 STEP STRESS PARAMETRIC FAILURE SUMMARY

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	1/1	A/B
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	1/1	A/B
125% 10 hr.	0	-	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
150% 10 hr.	0	-	0	-
15 hr.	1	A	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
175% 10 hr.	1	A	0	-
15 hr.	0	-	0	-
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-

GROUP II 160 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	1	A	0	-
100° C	1	A	0	-
125°C	0	-	0	-
150°C	0	-	0	-
175°C	2	A	0	-
200°C	1	A	0	-
225°C	0	-	1	B
250°C	5	B	2/2/4	A/C/B
275°C	1	B	1/1/3	A/C/B
300°C	0	-	0	-

GROUP III 16 HR. TEMP. STEPS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	1		0	-
175°C	0	-	1/2	A/B
200°C	1	A	0	-
225°C	2/1	A/D	0	-
250°C	2	A	0	-
275°C	2	A	3	B
300°C	0	-	1/2	A/B

MFR "A" = TEXAS INSTRUMENTS
MFR "B" = TELEDYNE

NOTES:
(A) $I_{D(OFF)}$ MAXIMUM LIMIT FAILURE
(B) $R_{ds(ON)}$ MAXIMUM LIMIT FAILURE
(C) $I_{D(OFF)}$ AND $r_{ds(ON)}$ MAXIMUM
(D) S/N 1208 (PULLED FOR MIL-19500 FAILURE)

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APPENDIX

FAILURE ANALYSIS

FAILURE ANALYSIS

Date 16 October 1978

J/N 2CN242-11B **P/N** 2N4856 **MFR** TELEDYNE

FAILURE VERIFICATION: Limit: 0.25 nA Max.

S/N	BV_{GS}	BV_{GS}	$V_{GS(OFF)}$ @ V_{DD} = 15V	$I_{D(OFF)}$ @V_{DD} = 15V V_{GS} = -10V	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
9179	50(Inv) (280 µA)	48(R) (5 mA)	6.7 leaky	2.5 µA	MP-11	$I_{D(OFF)}$
9181	45	56(R) (300 µA)	0.0 (+0.7V → on); -7.0 after BV_{GS} test.	V_{GS} = 0 = off; 1 nA after BV_{GS} test.	MP-10	$r_{ds(ON)}$
9189	48(R) (1.2mA)	49(R) (6.2mA)	Won't turn off (R)	250 µA (R)	MP-11	$I_{D(OFF)}$

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

FAILURE ANALYSIS

Date 16 October 1978

J/N 2CN242-11B **P/N** 2N4856 **MFR** TEXAS INSTRUMENTS

FAILURE VERIFICATION: Limit: 0.25 nA Max.

S/N	BV_{GD}	BV_{GS}	$V_{GS(OFF)}$ @ V_{DD} = 15V	$I_{D(OFF)}$ @ V_{DD} = 15V V_{GS} = -10V	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
1185	short	short	Always partly on (R) ±0.06→on	400 µA (stays on)	MP-11	I_D(OFF)
1189	49	200	Always off	250 nA	MP-11	I_D(OFF)
1192	35	120	0.0 (on @ +0.05 V) -8.9 V after BV_{GS} test.	14 µA (10 sec. to turn on). 7 nA after BV_{GS} test.	MP-11	$r_{ds(ON)}$

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

INTERNAL VISUAL

All six Texas Instruments and Teledyne samples have dark intermetallic formations on the source and drain metallization.

In addition, Serial Number 1185 (Texas Instruments) exhibits some melting and liquid metal flow toward the source contact edge of the die.

The glassivation is cracked up, particularly on the Texas Instruments parts. (See Figures A-1 and A-2.)

CONCLUSIONS

All these samples exhibit, in various degrees, the effects of surface charges and metal migration. The worst case is Texas Instruments sample number 1185, where actual melting of the aluminum has occurred. This has resulted in shorting the source and drain junctions. It is noteworthy that aluminum-silicon eutectic melts at 577°C, which indicates the extreme temperature reached by these samples.

Texas Instruments sample number 1192, and Teledyne sample number 9181 had surfaces so strongly inverted that they had changed to enhancement devices. As received for analysis Serial Number 1192 was "off" with $V_{GS=0}$, and required +0.05 volts on the gate to turn it on; Serial Number 9181 required +0.7 volts for turn on. Upon performing the BV_{GS} test at 50-120 volts, the device characteristics became almost normal, with gate turn-off voltages in the -7 to -9 volt range; and $I_{D(OFF)}$ reduced from the microamp to the nanoamp range.

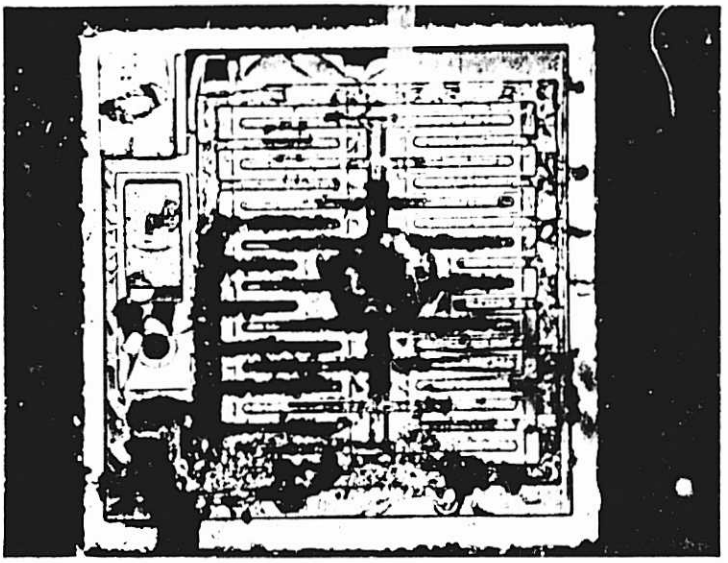

FIGURE A-1
S/N 1185. TEXAS INSTRUMENTS, 152X
Worst case sample showing intermetallics formation and melting of metallization.

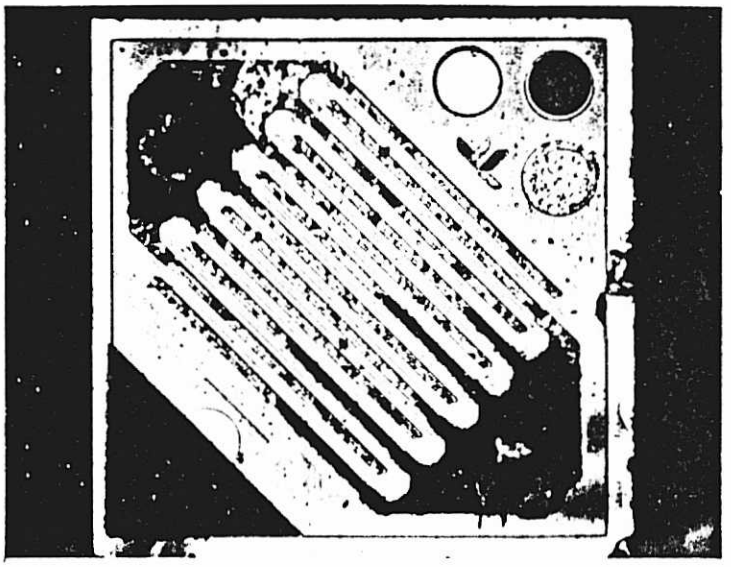

FIGURE A-2
S/N 9189. TELEDYNE, 124X
Typical sample showing intermetallics formation.